MULTIMEDIA UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 2, 2018/2019**

## ETM 7156 – MOBILE WIRELESS COMMUNICATIONS

13 MARCH 2019
1:30 PM – 4:30 PM
(3 Hours)

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**INSTRUCTIONS TO STUDENT**

1. This Question paper consists of 9 pages (including this cover page) with 5 Questions and 1 Appendix only.

2. Attempt **ALL FIVE** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided. Please number your answers clearly.

**Question 1**

(a) (i) Briefly describe the working principle of *cellular* systems. [3 marks]

(ii) Briefly explain with illustration of a diagram, the typical practice of cellular planning adopted for urban and rural areas. [4 marks]

(b) (i) Explain the origin of co-channel interference in a cellular system. [2 marks]

(ii) Can the signal-to-interference power ratio in a cellular system be increased by increasing the transmit power? Justify your answer. If you disagree, suggest an alternative method. [3 marks]

(c) A *blocked-calls-cleared* based cellular system has a total bandwidth of 19.2 MHz and each duplex channel requires 60 kHz. Assume that each user produces 0.2 Erlangs of traffic and a four-cell reuse pattern is used. An Erlang B table is provided in Appendix.

(i) Briefly describe the rationale behind the use of *trunking* in cellular networks. [2 marks]

(ii) Determine the number of channels in each cell. [2 marks ]

(iii) Suppose that each cell can support an amount of traffic intensity that is equivalent to 90% of the total number of channels per cell. Find the maximum number of users that can be accommodated in a cell, assuming that omnidirectional antennas are used at each base station. [2 marks]

(iv) Determine the blocking probability of the system. [2 marks ]

**Continued .....**

**Question 2**

(a) (i) Distinguish between large-scale and small-scale propagation models. [2 marks]

(ii) Discuss briefly the two major categories of factors influencing small-scale fading in both the time and frequency domains. [6 marks]

(b) The transmission tower of a base station, *T*, serves a housing area by providing digital transmission to receiver units, *R*, installed in houses, where the average receiver antenna height is 10 m. Standing in between the transmission tower and the receivers is a small hill which peaks at 35 m. The hill can be modeled as a knife-edge obstruction as shown in Fig. Q2.1. The carrier frequency is 3 GHz. Determine the knife-edge diffraction loss. The speed of light can be approximated as $3\times10^8$ m/s.

[*Hint*: The Fresnel-Kirchoff diffraction parameter is given as $v=\alpha\sqrt{\frac{2d_1d_2}{\lambda(d_1+d_2)}}$, where $\lambda$ is the wavelength and the interpretations of other symbols are shown in Fig. Q2.1. The diffraction loss can be calculated using the following equation.] [7 marks]

$$G_d(\text{dB})=\begin{cases}0, & v\le -1\\ 20\log_{10}(0.5-0.62v), & -1\le v\le 0\\ 20\log_{10}(0.5\exp(-0.95v)), & 0\le v\le 1\\ 20\log_{10}\left(0.4-\sqrt{0.1184-(0.38-0.1v)^2}\right) & 1\le v\le 2.4\\ 20\log_{10}\left(\frac{0.225}{v}\right), & v>2.4\end{cases}$$

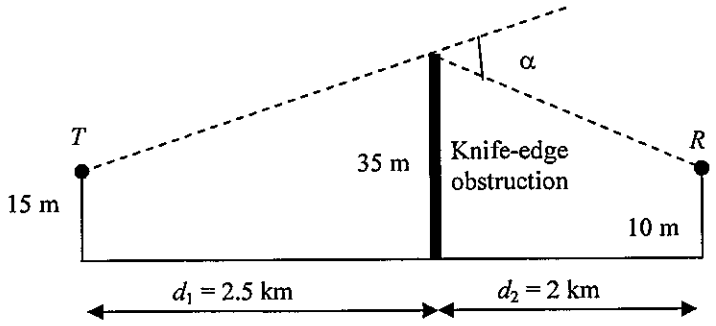


Fig. Q2.1

**Continued .....**

(c) A local spatial average of a power delay profile measured at 1.8 GHz is shown in Fig. Q2.2.

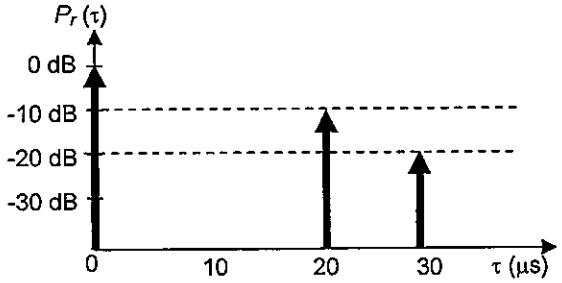


Fig. Q2.2

(i) Determine the mean excess delay and root mean square (rms) delay spread of the channel.

[Hint: The mean excess delay is given by $\bar{\tau} = \frac{\sum_k a_k^2 \tau_k}{\sum_k a_k^2} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)}$, where $a_k$ and $\tau_k$ are the real amplitudes and excess delays, respectively, of the $k$th multipath component.] [3 marks]

(ii) Can reliable signal transmission be achieved over this channel if a symbol interval of 1 μs is used? Briefly explain your answer. [2 marks]

**Continued .....**

**Question 3**

(a) (i) Briefly describe why the error performance of digital modulation in slow flat-fading channels is poorer than that in AWGN channels. Suggest two countermeasures for performance improvement. [3 marks]

(ii) Define the terms *power efficiency* and *bandwidth efficiency* of a modulation scheme. Briefly discuss the tradeoff between them. [4 marks]

(iii) Consider $M$-ary phase shift-keying ($M$-PSK) modulation schemes with the values of $M$ of 2, 4, 8, 16, 32 and 64. With proper justification, name the scheme with the lowest power efficiency and bandwidth efficiency, respectively. [2 marks]

(b) Given the received complex baseband signal of a binary phase-shift keying (BPSK) signal,

$$\tilde{x}(t) = \tilde{\alpha}(t)m(t) + \tilde{w}(t)$$

where $\tilde{\alpha}(t)$ is a complex Rayleigh flat-fading process, $\tilde{w}(t)$ is the channel noise, and

$$m(t) = \sum_k b_k p(t - kT),$$

in which $p(t)$ is the baseband pulse shaping function, $b_k \in \{\pm 1\}$ are the data symbols, and $T$ is the symbol period.

(i) With the aid of mathematical equations, design a symbol detection scheme which can estimate the slowly fading process based on pilot symbols transmitted at regular intervals throughout the course of data transmission. [6 marks]

(ii) Draw the block diagram of this pilot-based symbol detection scheme and show how the symbol $b_k$ can be estimated. [5 marks]

**Continued .....**

**Question 4**

(a) (i) With the aid of a diagram, describe the training mode and decision-directed mode in a linear adaptive channel equalizer. [5 marks]

(ii) In the context of adaptive filtering, briefly explain the following terms: 1) rate of convergence, 2) misadjustment. [3 marks]

(b) A wireless communication channel experiences $M$ independent Rayleigh fading channels. The receiver uses *selection combining* technique. Assume that all branches have identical average signal-to-noise ratio (*SNR*), $\Gamma$. In addition, the instantaneous *SNR* of each branch follows a Rayleigh distribution. If $\Gamma = 25$ dB and a specific *SNR* threshold, $\gamma$, is defined as 20 dB, answer the following questions.

[*Hint*: The probability that $M$ diversity branches *simultaneously* have instantaneous SNR less than a threshold $\gamma$ is given by $P_M(\gamma) = \left(1 - e^{\frac{-\gamma}{\Gamma}}\right)^M$ ].

(i) Briefly describe the principle of selection combining technique. [3 marks]

(ii) Determine the probability that a single branch has an instantaneous *SNR* value smaller than the threshold. [2 marks]

(iii) If $M = 5$ diversity branches are used, the probability that at least a single branch has instantaneous SNR greater than $\gamma$. [3 marks]

(iv) $M$, the number of diversity branches required, in order to sustain an outage probability of $10^{-6}$. [2 marks]

(v) Briefly explain how does *maximal-ratio combining* differ from selection combining. [2 marks]

**Continued .....**

## Question 5

(a) Briefly describe the following terms:

(i) Multiple-access [2 marks]

(ii) Duplexing [2 marks]

(b) (i) Between Frequency Division Multiplexing (FDM) and Orthogonal Frequency Division Multiplexing (OFDM), which multiplexing scheme is more spectral efficient? Justify your answer with the aid of diagrams. [5 marks]

(ii) With the aid of a frequency spectrum diagram, distinguish orthogonal frequency-division multiple access (OFDMA) from OFDM and state one application of OFDMA in modern wireless communication systems. [5 marks]

(c) Fig Q5 shows the logical separation of a Time Division Multiple Access/Time Division Duplex (TDMA/TDD) transmission system.

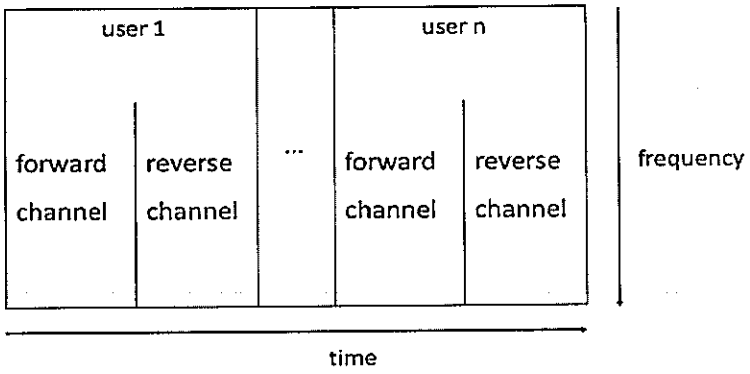


Fig. Q5

Using similar format, draw the logical separation diagram of the following transmission systems:

(i) Frequency Division Multiple Access/Frequency Division Duplex (FDMA/FDD) [2 marks]

(ii) FDMA/TDD [2 marks]

(iii) TDMA/FDD [2 marks]

**End of Questions**

## Appendix: Erlang B Table

### Erlang B Traffic Table

Maximum Offered Load Versus B and N
B is in %

| N/B | 0.01 | 0.05 | 0.1 | 0.5 | 1.0 | 2 | 5 | 10 | 15 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .0001 | .0005 | .0010 | .0050 | .0101 | .0204 | .0526 | .1111 | .1765 | .2500 | .4286 | .6667 |
| 2 | .0142 | .0321 | .0458 | .1054 | .1526 | .2235 | .3813 | .5954 | .7962 | 1.000 | 1.449 | 2.000 |
| 3 | .0868 | .1517 | .1938 | .3490 | .4555 | .6022 | .8994 | 1.271 | 1.603 | 1.930 | 2.633 | 3.480 |
| 4 | .2347 | .3624 | .4393 | .7012 | .8694 | 1.092 | 1.525 | 2.045 | 2.501 | 2.945 | 3.891 | 5.021 |
| 5 | .4520 | .6486 | .7621 | 1.132 | 1.361 | 1.657 | 2.219 | 2.881 | 3.454 | 4.010 | 5.189 | 6.596 |
| 6 | .7282 | .9957 | 1.146 | 1.622 | 1.909 | 2.276 | 2.960 | 3.758 | 4.445 | 5.109 | 6.514 | 8.191 |
| 7 | 1.054 | 1.392 | 1.579 | 2.158 | 2.501 | 2.935 | 3.738 | 4.666 | 5.461 | 6.230 | 7.856 | 9.800 |
| 8 | 1.422 | 1.830 | 2.051 | 2.730 | 3.128 | 3.627 | 4.543 | 5.597 | 6.498 | 7.369 | 9.213 | 11.42 |
| 9 | 1.826 | 2.302 | 2.558 | 3.333 | 3.783 | 4.345 | 5.370 | 6.546 | 7.551 | 8.522 | 10.58 | 13.05 |
| 10 | 2.260 | 2.803 | 3.092 | 3.961 | 4.461 | 5.084 | 6.216 | 7.511 | 8.616 | 9.685 | 11.95 | 14.68 |
| 11 | 2.722 | 3.329 | 3.651 | 4.610 | 5.160 | 5.842 | 7.076 | 8.487 | 9.691 | 10.86 | 13.33 | 16.31 |
| 12 | 3.207 | 3.878 | 4.231 | 5.279 | 5.876 | 6.615 | 7.950 | 9.474 | 10.78 | 12.04 | 14.72 | 17.95 |
| 13 | 3.713 | 4.447 | 4.831 | 5.964 | 6.607 | 7.402 | 8.835 | 10.47 | 11.87 | 13.22 | 16.11 | 19.60 |
| 14 | 4.239 | 5.032 | 5.446 | 6.663 | 7.352 | 8.200 | 9.730 | 11.47 | 12.97 | 14.41 | 17.50 | 21.24 |
| 15 | 4.781 | 5.634 | 6.077 | 7.376 | 8.108 | 9.010 | 10.63 | 12.48 | 14.07 | 15.61 | 18.90 | 22.89 |
| 16 | 5.339 | 6.250 | 6.722 | 8.100 | 8.875 | 9.828 | 11.54 | 13.50 | 15.18 | 16.81 | 20.30 | 24.54 |
| 17 | 5.911 | 6.878 | 7.378 | 8.834 | 9.652 | 10.66 | 12.46 | 14.52 | 16.29 | 18.01 | 21.70 | 26.19 |
| 18 | 6.496 | 7.519 | 8.046 | 9.578 | 10.44 | 11.49 | 13.39 | 15.55 | 17.41 | 19.22 | 23.10 | 27.84 |
| 19 | 7.093 | 8.170 | 8.724 | 10.33 | 11.23 | 12.33 | 14.32 | 16.58 | 18.53 | 20.42 | 24.51 | 29.50 |
| 20 | 7.701 | 8.831 | 9.412 | 11.09 | 12.03 | 13.18 | 15.25 | 17.61 | 19.65 | 21.64 | 25.92 | 31.15 |
| 21 | 8.319 | 9.501 | 10.11 | 11.86 | 12.84 | 14.04 | 16.19 | 18.65 | 20.77 | 22.85 | 27.33 | 32.81 |
| 22 | 8.946 | 10.18 | 10.81 | 12.64 | 13.65 | 14.90 | 17.13 | 19.69 | 21.90 | 24.06 | 28.74 | 34.46 |
| 23 | 9.583 | 10.87 | 11.52 | 13.42 | 14.47 | 15.76 | 18.08 | 20.74 | 23.03 | 25.28 | 30.15 | 36.12 |
| 24 | 10.23 | 11.56 | 12.24 | 14.20 | 15.30 | 16.63 | 19.03 | 21.78 | 24.16 | 26.50 | 31.56 | 37.78 |
| 25 | 10.88 | 12.26 | 12.97 | 15.00 | 16.13 | 17.51 | 19.99 | 22.83 | 25.30 | 27.72 | 32.97 | 39.44 |
| 26 | 11.54 | 12.97 | 13.70 | 15.80 | 16.96 | 18.38 | 20.94 | 23.89 | 26.43 | 28.94 | 34.39 | 41.10 |
| 27 | 12.21 | 13.69 | 14.44 | 16.60 | 17.80 | 19.27 | 21.90 | 24.94 | 27.57 | 30.16 | 35.80 | 42.76 |
| 28 | 12.88 | 14.41 | 15.18 | 17.41 | 18.64 | 20.15 | 22.87 | 26.00 | 28.71 | 31.39 | 37.21 | 44.41 |
| 29 | 13.56 | 15.13 | 15.93 | 18.22 | 19.49 | 21.04 | 23.83 | 27.05 | 29.85 | 32.61 | 38.63 | 46.07 |
| 30 | 14.25 | 15.86 | 16.68 | 19.03 | 20.34 | 21.93 | 24.80 | 28.11 | 31.00 | 33.84 | 40.05 | 47.74 |
| 31 | 14.94 | 16.60 | 17.44 | 19.85 | 21.19 | 22.83 | 25.77 | 29.17 | 32.14 | 35.07 | 41.46 | 49.40 |
| 32 | 15.63 | 17.34 | 18.21 | 20.68 | 22.05 | 23.73 | 26.75 | 30.24 | 33.28 | 36.30 | 42.88 | 51.06 |
| 33 | 16.34 | 18.09 | 18.97 | 21.51 | 22.91 | 24.63 | 27.72 | 31.30 | 34.43 | 37.52 | 44.30 | 52.72 |
| 34 | 17.04 | 18.84 | 19.74 | 22.34 | 23.77 | 25.53 | 28.70 | 32.37 | 35.58 | 38.75 | 45.72 | 54.38 |
| 35 | 17.75 | 19.59 | 20.52 | 23.17 | 24.64 | 26.44 | 29.68 | 33.43 | 36.72 | 39.99 | 47.14 | 56.04 |
| 36 | 18.47 | 20.35 | 21.30 | 24.01 | 25.51 | 27.34 | 30.66 | 34.50 | 37.87 | 41.22 | 48.56 | 57.70 |
| 37 | 19.19 | 21.11 | 22.08 | 24.85 | 26.38 | 28.25 | 31.64 | 35.57 | 39.02 | 42.45 | 49.98 | 59.37 |
| 38 | 19.91 | 21.87 | 22.86 | 25.69 | 27.25 | 29.17 | 32.62 | 36.64 | 40.17 | 43.68 | 51.40 | 61.03 |
| 39 | 20.64 | 22.64 | 23.65 | 26.53 | 28.13 | 30.08 | 33.61 | 37.72 | 41.32 | 44.91 | 52.82 | 62.69 |
| 40 | 21.37 | 23.41 | 24.44 | 27.38 | 29.01 | 31.00 | 34.60 | 38.79 | 42.48 | 46.15 | 54.24 | 64.35 |
| 41 | 22.11 | 24.19 | 25.24 | 28.23 | 29.89 | 31.92 | 35.58 | 39.86 | 43.63 | 47.38 | 55.66 | 66.02 |
| 42 | 22.85 | 24.97 | 26.04 | 29.09 | 30.77 | 32.84 | 36.57 | 40.94 | 44.78 | 48.62 | 57.08 | 67.68 |
| 43 | 23.59 | 25.75 | 26.84 | 29.94 | 31.66 | 33.76 | 37.57 | 42.01 | 45.94 | 49.85 | 58.50 | 69.34 |

(Continued on the next page)

## Appendix: Erlang B Table (continued)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 44 | 24.33 | 26.53 | 27.64 | 30.80 | 32.54 | 34.68 | 38.56 | 43.09 | 47.09 | 51.09 | 59.92 | 71.01 |
| 45 | 25.08 | 27.32 | 28.45 | 31.66 | 33.43 | 35.61 | 39.55 | 44.17 | 48.25 | 52.32 | 61.35 | 72.67 |
| 46 | 25.83 | 28.11 | 29.26 | 32.52 | 34.32 | 36.53 | 40.55 | 45.24 | 49.40 | 53.56 | 62.77 | 74.33 |
| 47 | 26.59 | 28.90 | 30.07 | 33.38 | 35.22 | 37.46 | 41.54 | 46.32 | 50.56 | 54.80 | 64.19 | 76.00 |
| 48 | 27.34 | 29.70 | 30.88 | 34.25 | 36.11 | 38.39 | 42.54 | 47.40 | 51.71 | 56.03 | 65.61 | 77.66 |
| 49 | 28.10 | 30.49 | 31.69 | 35.11 | 37.00 | 39.32 | 43.53 | 48.48 | 52.87 | 57.27 | 67.04 | 79.32 |
| 50 | 28.87 | 31.29 | 32.51 | 35.98 | 37.90 | 40.26 | 44.53 | 49.56 | 54.03 | 58.51 | 68.46 | 80.99 |
| 51 | 29.63 | 32.09 | 33.33 | 36.85 | 38.80 | 41.19 | 45.53 | 50.64 | 55.19 | 59.75 | 69.88 | 82.65 |
| 52 | 30.40 | 32.90 | 34.15 | 37.72 | 39.70 | 42.12 | 46.53 | 51.73 | 56.35 | 60.99 | 71.31 | 84.32 |
| 53 | 31.17 | 33.70 | 34.98 | 38.60 | 40.60 | 43.06 | 47.53 | 52.81 | 57.50 | 62.22 | 72.73 | 85.98 |
| 54 | 31.94 | 34.51 | 35.80 | 39.47 | 41.51 | 44.00 | 48.54 | 53.89 | 58.66 | 63.46 | 74.15 | 87.65 |
| 55 | 32.72 | 35.32 | 36.63 | 40.35 | 42.41 | 44.94 | 49.54 | 54.98 | 59.82 | 64.70 | 75.58 | 89.31 |
| 56 | 33.49 | 36.13 | 37.46 | 41.23 | 43.32 | 45.88 | 50.54 | 56.06 | 60.98 | 65.94 | 77.00 | 90.97 |
| 57 | 34.27 | 36.95 | 38.29 | 42.11 | 44.22 | 46.82 | 51.55 | 57.14 | 62.14 | 67.18 | 78.43 | 92.64 |
| 58 | 35.05 | 37.76 | 39.12 | 42.99 | 45.13 | 47.76 | 52.55 | 58.23 | 63.31 | 68.42 | 79.85 | 94.30 |
| 59 | 35.84 | 38.58 | 39.96 | 43.87 | 46.04 | 48.70 | 53.56 | 59.32 | 64.47 | 69.66 | 81.27 | 95.97 |
| 60 | 36.62 | 39.40 | 40.80 | 44.76 | 46.95 | 49.64 | 54.57 | 60.40 | 65.63 | 70.90 | 82.70 | 97.63 |
| 61 | 37.41 | 40.22 | 41.63 | 45.64 | 47.86 | 50.59 | 55.57 | 61.49 | 66.79 | 72.14 | 84.12 | 99.30 |
| 62 | 38.20 | 41.05 | 42.47 | 46.53 | 48.77 | 51.53 | 56.58 | 62.58 | 67.95 | 73.38 | 85.55 | 101.0 |
| 63 | 38.99 | 41.87 | 43.31 | 47.42 | 49.69 | 52.48 | 57.59 | 63.66 | 69.11 | 74.63 | 86.97 | 102.6 |
| 64 | 39.78 | 42.70 | 44.16 | 48.31 | 50.60 | 53.43 | 58.60 | 64.75 | 70.28 | 75.87 | 88.40 | 104.3 |
| 65 | 40.58 | 43.52 | 45.00 | 49.20 | 51.52 | 54.38 | 59.61 | 65.84 | 71.44 | 77.11 | 89.82 | 106.0 |
| 66 | 41.38 | 44.35 | 45.85 | 50.09 | 52.44 | 55.33 | 60.62 | 66.93 | 72.60 | 78.35 | 91.25 | 107.6 |
| 67 | 42.17 | 45.18 | 46.69 | 50.98 | 53.35 | 56.28 | 61.63 | 68.02 | 73.77 | 79.59 | 92.67 | 109.3 |
| 68 | 42.97 | 46.02 | 47.54 | 51.87 | 54.27 | 57.23 | 62.64 | 69.11 | 74.93 | 80.83 | 94.10 | 111.0 |
| 69 | 43.77 | 46.85 | 48.39 | 52.77 | 55.19 | 58.18 | 63.65 | 70.20 | 76.09 | 82.08 | 95.52 | 112.6 |
| 70 | 44.58 | 47.68 | 49.24 | 53.66 | 56.11 | 59.13 | 64.67 | 71.29 | 77.26 | 83.32 | 96.95 | 114.3 |
| 71 | 45.38 | 48.52 | 50.09 | 54.56 | 57.03 | 60.08 | 65.68 | 72.38 | 78.42 | 84.56 | 98.37 | 116.0 |
| 72 | 46.19 | 49.36 | 50.94 | 55.46 | 57.96 | 61.04 | 66.69 | 73.47 | 79.59 | 85.80 | 99.80 | 117.6 |
| 73 | 47.00 | 50.20 | 51.80 | 56.35 | 58.88 | 61.99 | 67.71 | 74.56 | 80.75 | 87.05 | 101.2 | 119.3 |
| 74 | 47.81 | 51.04 | 52.65 | 57.25 | 59.80 | 62.95 | 68.72 | 75.65 | 81.92 | 88.29 | 102.7 | 120.9 |
| 75 | 48.62 | 51.88 | 53.51 | 58.15 | 60.73 | 63.90 | 69.74 | 76.74 | 83.08 | 89.53 | 104.1 | 122.6 |
| 76 | 49.43 | 52.72 | 54.37 | 59.05 | 61.65 | 64.86 | 70.75 | 77.83 | 84.25 | 90.78 | 105.5 | 124.3 |
| 77 | 50.24 | 53.56 | 55.23 | 59.96 | 62.58 | 65.81 | 71.77 | 78.93 | 85.41 | 92.02 | 106.9 | 125.9 |
| 78 | 51.05 | 54.41 | 56.09 | 60.86 | 63.51 | 66.77 | 72.79 | 80.02 | 86.58 | 93.26 | 108.4 | 127.6 |
| 79 | 51.87 | 55.25 | 56.95 | 61.76 | 64.43 | 67.73 | 73.80 | 81.11 | 87.74 | 94.51 | 109.8 | 129.3 |
| 80 | 52.69 | 56.10 | 57.81 | 62.67 | 65.36 | 68.69 | 74.82 | 82.20 | 88.91 | 95.75 | 111.2 | 130.9 |
| 81 | 53.51 | 56.95 | 58.67 | 63.57 | 66.29 | 69.65 | 75.84 | 83.30 | 90.08 | 96.99 | 112.6 | 132.6 |
| 82 | 54.33 | 57.80 | 59.54 | 64.48 | 67.22 | 70.61 | 76.86 | 84.39 | 91.24 | 98.24 | 114.1 | 134.3 |
| 83 | 55.15 | 58.65 | 60.40 | 65.39 | 68.15 | 71.57 | 77.87 | 85.48 | 92.41 | 99.48 | 115.5 | 135.9 |
| 84 | 55.97 | 59.50 | 61.27 | 66.29 | 69.08 | 72.53 | 78.89 | 86.58 | 93.58 | 100.7 | 116.9 | 137.6 |
| 85 | 56.79 | 60.35 | 62.14 | 67.20 | 70.02 | 73.49 | 79.91 | 87.67 | 94.74 | 102.0 | 118.3 | 139.3 |
| 86 | 57.62 | 61.21 | 63.00 | 68.11 | 70.95 | 74.45 | 80.93 | 88.77 | 95.91 | 103.2 | 119.8 | 140.9 |
| 87 | 58.44 | 62.06 | 63.87 | 69.02 | 71.88 | 75.42 | 81.95 | 89.86 | 97.08 | 104.5 | 121.2 | 142.6 |
| 88 | 59.27 | 62.92 | 64.74 | 69.93 | 72.82 | 76.38 | 82.97 | 90.96 | 98.25 | 105.7 | 122.6 | 144.3 |
| 89 | 60.10 | 63.77 | 65.61 | 70.84 | 73.75 | 77.34 | 83.99 | 92.05 | 99.41 | 107.0 | 124.0 | 145.9 |
| 90 | 60.92 | 64.63 | 66.48 | 71.76 | 74.68 | 78.31 | 85.01 | 93.15 | 100.6 | 108.2 | 125.5 | 147.6 |

**End of Paper**